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Habitat Relationships of Deer and Ruffed Grouse in Central Wisconsin

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Abstract

This study was conducted to determine changes in forest composition in the Central Forest Region (CFR) of Wisconsin and to assess the effects of these changes on white-tailed deer (*Odocoileus virginianus*) and ruffed grouse (*Bonasa umbellus*). Changes in forest composition were estimated from U.S. Forest Service and Wisconsin Department of Natural Resources (DNR) forest inventories. Deer trail counts were conducted during 1985-87 within the Black River State Forest and Jackson County Forest, in eastern Jackson County. Analyses were made to determine differences in deer use (the number of deer trails/transect segment) within the principal overstory, understory, and ground-layer habitats. Surveys were also conducted to determine vegetative characteristics and the density of ruffed grouse in red pine plantations on sites converted from oak and aspen.

Projected habitat changes on state and county properties in the CFR indicated a 66% increase in red and white pine between 1992 and 2002. By comparison, oak is projected to decline 31%. Little or no change is projected in aspen-white birch and jack pine.

Deer trail abundance suggested a strong preference for open, aspen, and jack pine habitats. Lower deer use occurred in oak and red pine habitats. Generally, deer use increased with deciduous saplings/tall shrubs present in the understory of upland habitats, and to a lesser extent with pine saplings.

Drumming grouse densities averaged 1.7 birds/100 acres in 15- to 29-year-old red pine plantations compared to 0.2 birds/100 acres in 43- to 57-year-old red pine plantations. Grouse drumming sites were located in portions of pine plantations with the highest woody stem density; however, stem densities at these sites were less than recommended for optimum grouse habitat.

Open, aspen, and jack pine were valuable habitats for deer in this study. Conversion of oak to red pine or white pine plantations must be approached cautiously. Although it was not demonstrated that oak was a preferred deer habitat in this study, its importance to deer, ruffed grouse, and other wildlife has been documented elsewhere. Loss of oak habitats is expected to occur due to mortality from oak wilt and the gypsy moth (*Lymantia dispar*) and natural succession to white pine.

If the management objective is to maintain the existing deer habitat suitability in central Wisconsin, we recommend maintaining as much of the existing open, aspen, and jack pine habitats as possible. The detrimental effect of conversion of these habitats to red or white pine plantations can be lessened by allowing understory and ground-layer food and cover plants to thrive. Additionally, maintaining high interspersion of forest types and age classes may partially mitigate the negative impact of pine conversion on deer. Alternatively, if some areas are to be managed to maximize timber production, the reduction in local deer habitat suitability should be offset by enhancing deer habitat suitability on other nearby sites.

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Introduction

Guidelines for defining forest habitat management priorities were developed in 1970 and revised in 1981 (Wisconsin Department of Natural Resources Policies and Procedures Manual Code [MC] 2112). These guidelines apply to all forest lands managed by the Department of Natural Resources (DNR) north of State Highway 21 and all county forest lands with approval of county forestry committees. Forest habitat guidelines for deer recommend that no more than 25% of a forest planning area should be occupied by shade-tolerant types (northern hardwoods, mixed hardwoods, and balsam fir[1]) and conifer plantations where a fall density of 30+ deer/mi^2 is desired.

These guidelines were based, in part, on a study in northwestern Wisconsin (Kohn 1974) in which the oak-aspen type contained four times as many deer as pine plantations, and deer densities were reduced by half where 50-60% of the oak and aspen had been converted to pine. It was also recommended that no more than 30% of a sandy soil area should be in pine plantation to maintain a summer density of 25 deer/mi^2. Because climatic conditions in northern Wisconsin result in lower deer carrying capacity than in the Central Forest Region (CFR), the relevance of these compositional guidelines for the CFR were questioned.

In the CFR, overwinter deer population goals average 28 deer/mi^2 (range 25-30) in five deer management units (53, 54A, 55, 56, and 58). These goals result in fall deer densities that usually exceed 40 deer/mi^2.

Habitat trends in the CFR could negatively affect deer and ruffed grouse. Natural succession is expected to result in a decrease in aspen and oak, and a corresponding increase in white pine and red maple (Kotar et al. 1988, Kotar and Burger 1991). Additionally, there is concern that conversion of oak to red pine plantations on public lands, and conversion of openings, oak, and jack pine to red pine on private industrial forest lands could reduce the suitability of habitats for deer and ruffed grouse in central Wisconsin. Oak has been well documented to be important for deer, ruffed grouse, and other wildlife (Korschgen 1962, Shaw 1971, Sander 1977). Additional concern exists about the loss of forested habitats to agricultural crop fields on other private lands.

This study was conducted from 1985-87 to re-evaluate current habitat compositional guidelines, particularly the proportion of red, white, and jack pine prescribed for public lands in the CFR. The specific objectives of this study were to document the extent of past and future habitat change in the region, and to relate habitat selection by deer and ruffed grouse to species composition and age of natural and artificially regenerated conifer stands.

Since the inception of this study, there has been a growing trend toward ecosystem management. This study provides information on the effects of forest management practices on habitat use by deer and ruffed grouse. This information and the habitat needs of other wildlife species should be considered in the development of ecosystem management plans for the CFR.

Study Area

Habitat changes between 1968 and 1983 were determined for the seven counties within the CFR from U.S. Forest Service inventories conducted in 1968 and 1983 (Spencer and Thorne 1972, Hahn 1985). The CFR includes both public and private commercial forest land (CFL) in Adams, Clark, Eau Claire, Jackson, Juneau, Monroe, and Wood counties.

Research to determine deer and ruffed grouse habitat relationships was conducted on the 65,700-acre Black River State Forest (BRSF) and the 102,550-acre Jackson County Forest (JCF) in eastern Jackson County. Eighty-three percent of surface area is CFL. Non-forested wetlands, which include lowland brush, marsh, and water occupy the remainder of these properties. The overstory composition of CFL was 30% oak, 24% jack pine, 23% aspen-white birch, 9% red pine, 9% white pine, and 5% miscellaneous (swamp conifers, mixed hardwoods, offsite aspen, upland brush, and grass). Upland forests occurred on sites with dry, nutrient-poor sandy soils that historically supported oak and pine barrens habitats.

Five forest survey units that varied from 9,577 to 12,964 acres, and totaled 58,561 acres were designated for study. Survey units were selected to represent a broad range of conifer composition, from 27% of CFL to 79% on the five survey units. The principal overstory habitat types within the five forest survey units were: open (grass-forb and upland brush); aspen (trembling and large-toothed aspen and white birch); oak (jack-, black, and white oak most prevalent); jack pine; red pine; white pine; mixed hardwoods (red maple, silver maple, American elm, and white ash); swamp conifers (black spruce and tamarack); and marsh (bluejoint

[1] Scientific names of plants are located in Appendix B.1

grass-sedge, willow, speckled alder, bog birch, and various species associated with muskegs) (Appendix A.1).

Species of tall shrubs within the understory include hazel-nut, gray dogwood, chokeberry, blackberry, and red raspberry. Ground-layer shrubs included blueberry, sweetfern, huckleberry, dewberry, and wintergreen.

Ruffed grouse were censused on 2,132 acres within 17 red pine plantations that represented sites converted from oak and aspen on state and county forest lands in eastern Jackson County. Stands varied from 15 to 57 years of age in spring 1987 and ranged from 8 to 297 acres. Stand ages are based on the year of planting; seedlings were 2 years old when planted.

The 17 surveyed plantations occurred on sites classified by Kotar and Burger (1991) as PGy (white pine/huckleberry), PRhI (white pine/dewberry/winterberry), and PCr (white pine/gray dogwood). The PGy type occurs on dry sites and is generally accompanied by jack-oak, white oak, red pine, and jack pine. Low sweet blueberry, bracken fern, service-berry, and huckleberry are prevalent understory species. The PRhI type occurs on wetter sites where white pine and red maple thrive. Diagnostic species include swamp dewberry, bunchberry, goldthread, cinnamon fern, and winterberry. The PCr type is similar to PGy with choke cherry, gray dogwood, and false Solomon's seal most prevalent. Additional descriptions of the red pine stands where surveys of ruffed grouse were conducted are given in Appendix A.2.

Methods

Habitat Change

Hahn (1985) determined the area of major land-use classes for the CFR by interpreting aerial photography and field surveys of ground plots. We compared these findings to similar inventory data collected in 1968 (Spencer and Thorne 1972). Projected future changes in forest composition on county and state properties were based on DNR forest reconnaissance data (Wisconsin Department of Natural Resources, Bureau of Forestry, unpublished data).

DNR PHOTO

Deer habitat use was assessed from trail counts.

Evaluation of Habitat Use by Deer

Deer habitat use was assessed from trail counts (McCaffery 1976). Trail counts were conducted in November 1985-87 on 40 quarter-mile randomly distributed transects in each of the five forest survey units. Deer trail transects were located using U.S. Geological Survey quadrangles (1:24,000) and BRSF and JCF inventory records and maps. Randomized starting points for transects were chosen by section numbers and 40-acre land descriptions. The transect starting points were situated where driveable roads or woods trails entered a section and forty. Transect direction was predetermined on one of four azimuths (45°, 135°, 225°, and 315°), provided no obstacles (open water, drainage ditches, or other natural barriers) would have prevented completion of the entire transect. Each transect was comprised of five contiguous 4-chain (264 ft) segments. Because each transect could encompass several habitat types, we used the transect segment as the experimental unit.

Each transect segment was categorized to one of nine principal overstory habitat types. Segments

were also classed relative to the presence or absence of understory woody cover (deciduous saplings/tall shrubs or pine saplings) and ground-layer forage (perennial herbs or low-growing shrubs). Plants were considered present in a segment if one or more species were encountered within 66 ft of the observer. In addition to tree saplings of overstory species listed above, tall shrubs (capable of exceeding 4 ft in height), and ground-layer shrubs were recorded.

Differences in the mean number of deer trails/segment among the nine principal overstory habitat types were determined with Kruskal-Wallis tests (Conover 1980). The effects of the presence of understory cover and ground-layer forage within overstory types were also analyzed with Kruskal-Wallis tests. Pair-wise comparisons were made using Bonferroni adjusted critical values (Miller 1981) to preserve the overall error rate of $P \leq 0.05$. It was recognized that contiguous transect segments were not independent and that the number of deer trails crossing adjacent segments were likely correlated. Therefore, the reported *P*-values are likely biased, but they provide an index to the magnitude of the differences in deer use of habitat types. In addition, correlation analyses were used to assess the relationship between the number of deer trails/transect and the percentage of the transect composed of red, white, or jack pine. Data were analyzed using the Statistical Analysis System (SAS 1989).

Ruffed Grouse Habitat Evaluation

Drumming ruffed grouse were censused during April and May from 1986 to 1988 by locating all drumming males on the study sites (Gullion 1966). Vegetation was measured during summer 1987 in 13 of the 17 red pine plantations on converted sites surveyed for ruffed grouse. Six of the plantations were 20-26 years old; seven were 48-57 years old. Four of the red pine plantations censused for ruffed grouse were not sampled for vegetation: two were small (8 and 23 acres) and poorly stocked with red pine; another was dominated by a white pine understory; and the fourth was fragmented into small stands of red pine. Stand size averaged 149 acres (range = 55-297 acres) among 13 stands surveyed (additional descriptions of stands are given in Appendix A.2).

PHOTO: J. KUBISIAK

Locations of drumming male grouse were mapped in 17 red pine plantations on converted sites.

Vegetation Surveys in Red Pine Plantations on Converted Sites

A randomly located starting position was established by throwing a stake into the stand from an entry point near a corner of the stand. Vegetative measurements were made at temporary points 2-4 chains (132-264 ft) apart, and distributed throughout the stand.

The number and species of trees $\geq$ 5 in dbh, saplings < 5 in dbh, and shrubs > 5 ft tall were counted on 0.01-acre circular plots centered at each point. In addition, the number of dead stems > 5 ft tall was also counted. The same procedures were used to measure woody vegetation on 0.01-acre circular plots centered on the stage of each ruffed grouse drumming log. Canopy coverage of pine, hardwood, and open (no overhead cover) was estimated using a densiometer with a 100-square grid convex mirror.

Ground-layer species composition and coverage ($\geq$ 5% of the plot) were estimated within a 24 x 30 in (5 ft^2) quadrat centered and oriented to the northeast quadrant of each 0.01-acre circular plot. Coverage was also estimated for tree saplings < 5 in dbh and shrubs below waist-height within the quadrat. Coverage of plants extending over the quadrat but rooted outside was estimated, but was excluded from the frequency calculation.

Data were summarized by stand and subsequently combined into the two principal overstory age groups. An importance value (IV) was derived from the average of relative frequency and relative dominance (Curtis 1959, Ohmann and Ream 1971).

Results and Discussion

Habitat Change

The acreage of CFL within the CFR occupied by oak increased 21% from 561,700 acres in 1968 to 681,500 acres in 1983. Red pine, jack pine, and white pine each increased 14% during the same period (Figure 1, Appendix A.3). Red pine increased from 71,200 acres in 1968 to 81,200 acres in 1983; white pine from 41,900 acres in 1968 to 47,800 acres in 1983; and jack pine from 170,400 acres in 1968 to 194,300 acres in 1983. By comparison, aspen-white birch remained stable at about 463,000 acres.

The acreage of red pine is forecasted to increase about 48% (from 28,788 acres in 1992 to 42,586 in 2002) on state and county forests in the CFR (Figure 2). White pine is projected to increase 90% from 21,329 acres in 1992 to 40,481 acres in 2002. Meanwhile, oak acreage is projected to decline by 31% from 85,850 acres in 1992 to 59,441 in 2002. Aspen-white birch occupied 126,909 acres in 1992; jack pine 54,492 acres; and other habitats 20,238 acres. These habitats are projected to change very little.

Public lands have proportionally more pine and less oak than private lands. State and county properties comprised only 19% of the CFL in the CFR in 1983 (Hahn 1985); however, 28% of the jack pine, 35% of the red pine, and 45% of the white pine in the CFR occurred on state and county forest properties. Only 13% of the oak occurred on public lands.

DNR forest reconnaissance inventories indicated that pine stands averaged < 30 acres in size in the CFR during the last half century (Table 1). Size of red pine plantations varied considerably by ownership, but tended to be largest on the BRSF and JCF (Table 2). Sixty-six percent of the red pine plantations were > 20 acres on the BRSF compared to 44% on the JCF and 35% on the other county forests in the CFR.

The predicted reduction in the acreage of oaks is cause for concern, given the importance of oaks as food for 186 species of birds and mammals (Van Dersal 1940). While conifers, including red and white pine, provide important thermal cover for deer, wild turkeys (*Meleagris gallopavo*), and many other wildlife species, oaks are widely recognized as important food sources for deer, ruffed grouse, wild turkey, squirrels (*Sciurus* spp.), and wood ducks (*Aix sponsa*) (Shaw 1971, Sander 1977). In central Wisconsin, oaks have the potential for some acorn production in most years, and good-to-excellent yields about every four years (J. Kubisiak, Wisconsin Department of Natural Resources, unpublished data). In addition, oaks provide habitat for woodpeckers, other cavity nesters, passerine birds, small mammals, reptiles, amphibians, and other forest wildlife (Pfannmuller 1990).

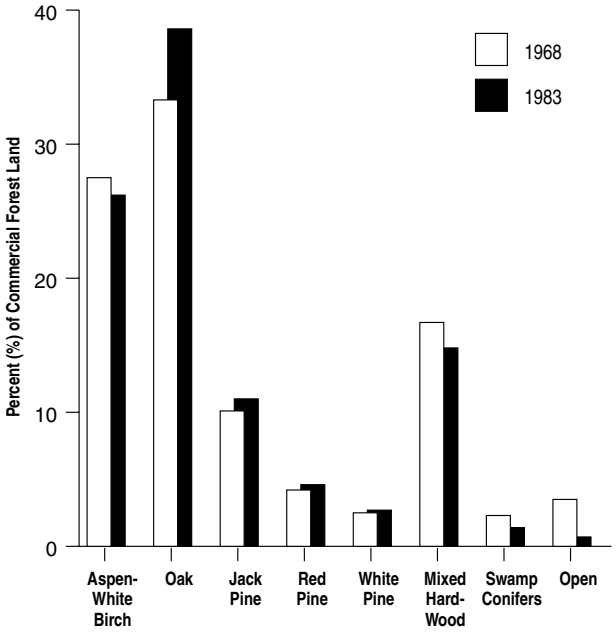


Figure 1. *Habitat changes in the Central Forest Region of Wisconsin (Hahn 1985, Spencer and Thorne 1972).*

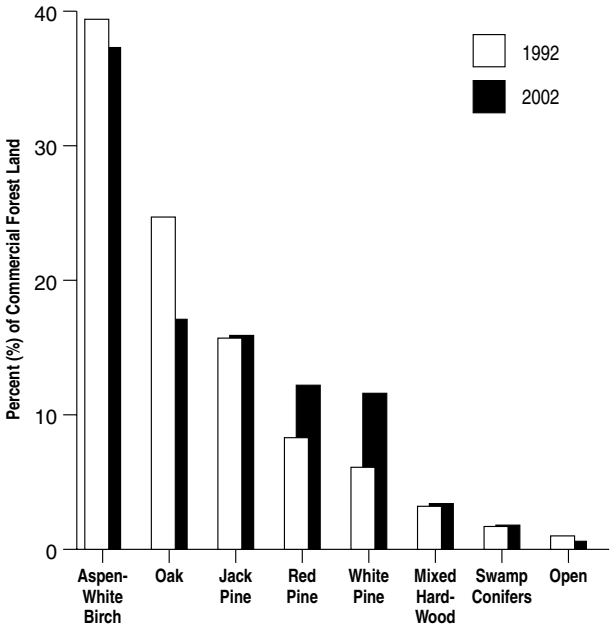


Figure 2. *Projected habitat changes on State and County Forests in the Central Forest Region of Wisconsin (DNR forest reconnaissance).*

Table 1. *Mean (± SE) pine plantation size (acres), by age class and species on county and state forest lands in the Central Forest Region, 1992. Number of stands in parentheses.*[a]

	Age Class (years)			
Forest Type	**0-25**	**26-50**	**≥ 51**	**All Ages**
Red pine	31.4 ± 2.1 (249)	23.6 ± 1.2 (504)	29.0 ± 2.5 (160)	26.6 ± 1.0 (913)
Jack and white pine[b]	24.1 ± 3.0 (40)	29.2 ± 4.5 (101)	31.4 ± 3.1 (84)	29.1 ± 2.4 (225)
Red, jack, and white pine	30.4 ± 1.8 (289)	24.5 ± 1.3 (605)	29.9 ± 2.0 (244)	27.1 ± 0.9 (1,138)

[a] DNR forest reconnaissance.

[b] These species were combined since a small number of stands occurred in 0- to 25-year-old white pine and jack pine 26 years and older.

Table 2. *Mean (± SE) pine plantation size (acres), by age class and property, on county and state forest lands in the Central Forest Region, 1992. Number of stands in parentheses.*[a]

	Age Class (years)			
Forest Property	**0-25**	**26-50**	**≥ 51**	**All Ages**
Black River State	46.0 ± 4.6 (46)	33.6 ± 3.7 (58)	57.7 ± 7.4 (32)	43.4 ± 2.9 (136)
Jackson County	39.6 ± 6.9 (56)	31.9 ± 5.7 (74)	27.4 ± 7.1 (15)	34.4 ± 4.0 (145)
Clark County	27.0 ± 3.2 (46)	17.7 ± 1.2 (166)	19.4 ± 1.9 (46)	19.7 ± 1.1 (258)
Eau Claire County	20.2 ± 2.0 (50)	22.6 ± 1.6 (97)	12.3 ± 1.9 (23)	20.4 ± 1.2 (170)
Juneau County	29.6 ± 7.6 (18)	28.1 ± 5.5 (37)	27.8 ± 6.8 (29)	28.3 ± 3.7 (84)
Monroe County	21.6 ± 5.6 (10)	24.4 ± 5.6 (12)	—	23.1 ± 3.8 (22)
Wood County	21.0 ± 3.1 (23)	18.3 ± 2.6 (60)	27.3 ± 4.3 (15)	20.3 ± 1.5 (98)
All Units Combined	31.4 ± 2.1 (249)	23.6 ± 1.2 (504)	29.0 ± (160)	26.6 ± 1.0 (913)

[a] DNR forest reconnaissance.

Some loss of oak habitats will occur due to mortality from oak wilt. Five to 10 percent of the oak acreage in the CFR is estimated to be infected (D. J. Hall, Wisconsin Department of Natural Resources, pers. comm.). The gypsy moth poses another threat to oak in Wisconsin since it has the potential to cause considerable mortality of overstory trees. Recently concern has tempered somewhat, since the acreage infected by gypsy moths declined from 7 to 1 million between 1990 and 1994 in 18 northeastern states including Michigan (U.S. Forest Service 1995). Cause of this decline appears to be due largely to a fungus (*Entomophaga maimaiga*).

Additional loss of oak and aspen habitats will likely occur due to natural succession to white pine. Although data specific to the CFR were not reported by Hahn (1985), white pine occupied 11%, and red pine 1% of the understory in oak acreage during 1983 in a larger 13-county region in central Wisconsin. By comparison, white pine occupied

PHOTO: J. KUBISIAK

Natural succession of oak, aspen, and grass-upland brush habitats to white pine may reduce habitat suitability for deer and ruffed grouse.

8%, and red pine 1% of the aspen-white birch acreage in the 13-county region. Natural succession to white pine, together with forced conversion to red pine, could result in a loss of habitats important to deer and ruffed grouse, unless understory and ground-layer plants important to deer are encouraged within pine stands.

The relatively high proportion of pine and low proportion of oak on public land in the CFR may adversely affect deer. However, this may be offset by the interspersion with natural openings, aspen, jack pine, and wetland habitats. Although not indicated in the forest inventory, oak also frequently occurs as a viable understory species in aspen and jack pine habitats in the CFR. In addition, crop and fallow fields on adjacent private lands may further offset the negative effect of the high concentration of pine on public lands.

Conversion of existing oak acreage to red or white pine may result in an increase in the number or average size of pine plantations or the proximity of plantations to each other. Larger plantations or plantations in closer proximity will reduce heterogeneity of habitats.

Although DNR forest reconnaissance data project no change in jack pine acreage on state and county forests during 1992-2002, concern about possible loss of jack pine in the region has recently been expressed (D. J. Hall, Wisconsin Department of Natural Resources, pers. comm.). Many jack pine stands have been damaged by wind, ice storms, and insects, particularly the jack pine budworm (*Choristoneura pinus*), during the last 5-10 years in the CFR. Following salvage cuts, many of these stands are often replaced by red pine plantations, particularly on private industrial forest lands. Inadequate jack pine regeneration has also followed regeneration cuts in many other stands, and in most cases resulted in an understory dominated by sedge, various other ground-layer species, or oak. A concerted effort has been made to artificially regenerate jack pine to maintain commercially operable stands to address this problem.

Deer Habitat Use

Overstory Habitat Type

The mean number of trails/transect segment differed (χ^2 = 239.78, 8 df, P< 0.001) among the nine forest habitat types (Table 3). Highest trail abundance occurred in swamp conifer, open, and marsh habitats where understory and/or ground-layer forage was often abundant. Greater trail abundance in wetland habitats was due, in part, to the persistence of trails from year to year in the soft substrate, and little or no overstory litter to obliterate trails. While cutting may occur in swamp conifers, wetland habitats would likely be left unmanaged on public lands.

Table 3. *Index of deer use of the principal overstory habitats.*

Overstory Type	No. of Segments	Mean (± SE) Deer Trails/Segment
Swamp conifers	72	1.81 ± 0.17
Open	92	1.62 ± 0.13
Marsh	62	1.40 ± 0.15
Aspen	495	1.21 ± 0.05
Jack pine	672	1.15 ± 0.04
White pine	293	0.91 ± 0.06
Mixed hardwoods	103	0.77 ± 0.09
Oak	833	0.69 ± 0.03
Red pine	378	0.58 ± 0.04

PHOTO: J. KUBISIAK

Aspen and jack pine habitats with deciduous understories were the most preferred by deer of the upland forested habitats.

Table 4. *Significance[a] level of paired comparisons of deer use among the principal overstory habitats.*

Overstory Type	Open	Marsh	Aspen	Jack Pine	White Pine	Mixed Hardwoods	Oak	Red Pine
Swamp conifers	NS[b]	NS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Open		NS	NS	<0.001	<0.001	<0.001	<0.001	<0.001
Marsh			NS	NS	NS	<0.001	<0.001	<0.001
Aspen				NS	<0.001	<0.001	<0.001	<0.001
Jack pine					<0.001	<0.001	<0.001	<0.001
White pine						NS	NS	<0.001
Mixed hardwoods							NS	NS
Oak								NS

[a] Bonferroni adjusted critical value $\alpha = 0.001$.

[b] Not significant, $P > 0.001$.

Deer use was greater (χ^2 = 11.99-91.22, 1 df, P = 0.0001-0.0005) in open, aspen, and jack pine than in white pine, oak, and red pine habitats (Table 4). Deer use of oak was similar (χ^2 = 7.13-8.80, 1 df, P = 0.003-0.008) to white and red pine habitats, even during 1985 (χ^2 = 0.01-5.10, 1 df, P = 0.024-0.936), when greater deer use of oak might have been expected due to an excellent acorn yield. We cannot explain why deer use of oak remained low in 1985, in light of other studies that indicated the importance of acorns to deer, whatever the yield (Korschgen 1962, Shaw 1971, Sander 1977).

Deer use declined as the proportion of the overstory occupied by red pine increased from 0% to 100% (r = -0.89, n = 6, P = 0.016, Figure 3). In contrast, the positive correlation between deer use and the proportion of the overstory composed of jack pine approached statistical significance (r = 0.76, n = 6, P = 0.082). Deer use was not correlated with the amount of white pine in the overstory (r = -0.26, n = 6, P = 0.607).

Estimates of deer use of forest cover types may be biased. Overcounting may have occurred in lowland habitats; however, these habitats were not the principal target of the study. Deer movement between preferred upland habitats that were separated by lowland and open types may have contributed to higher deer use in these types, but this was not determined, and would have been difficult to measure. In contrast, undercounting may have occurred within oak habitats where current leaf litter might have obscured some trails. Deer would also be expected to disperse and not form trails as readily in habitats with little or no woody cover or ground-layer forage. Varying

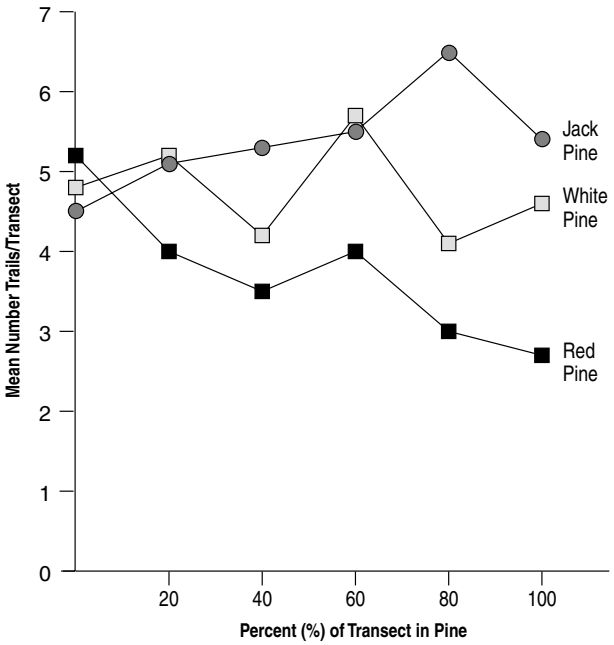


Figure 3. *Number of deer trails/transects versus percent of transect with pine overstory.*

proportions of oak, aspen, red pine, white pine, jack pine, and mixed hardwoods were in this category.

While year-to-year persistence and observability of deer trails would be expected to differ within the various habitats, we do not believe these factors significantly biased the results of this study. In addition, it was not determined whether or how much the spatial arrangement and size of habitats affected deer use. Deer populations remained relatively stable during the study, minimizing the possibility that changing deer numbers biased

PHOTO: J. KUBISIAK

The growth form of jack pine allows sunlight to reach understory and ground-layer plants.

observed patterns of habitat use. Estimated fall deer densities in Deer Management Unit 55 (the management unit that contained BRSF and JCF) was 46/mi^2 in 1985, 51/mi^2 in 1986, and 45/mi^2 in 1987 (K. R. McCaffery, Wisconsin Department of Natural Resources, pers. comm.).

Results, except for oak, corroborated earlier findings on the relative importance of aspen, open, and jack pine as deer habitats in Wisconsin. The mean number of deer trails/segment was 1.34 in aspen compared to 1.14 in oak and jack pine, and 0.90 in red-white pine habitats in central and northern Wisconsin surveys conducted during 1968-73 (McCaffery 1976). In a study within a major pinery of northwest Wisconsin, Kohn (1974) found four times as much deer activity in aspen-oak habitats as in red and jack pine plantations. In another study in northern Wisconsin on quite different sandy loam soils, high deer use occurred in the 412-acre Anniversary Red Pine Plantation (ARPP) that contained numerous grassy openings (McCaffery and Ashbrenner 1991).

McCaffery (1986) using data from Byelich et al. (1972) found a strong correlation ($r = 0.83$) between the adult buck harvest and the abundance of aspen, oak, jack pine, and non-stocked forest land in Michigan. Habeck and Curtis (1959) also indicated that forest communities composed of aspen, jack pine, and white birch provided excellent summer range for deer. In northern Wisconsin, aspen leaves and grasses comprised the principal foods of deer during April-November based on analyses of rumina from 76 road-killed deer (McCaffery et al. 1974). These studies indicated that aspen, oak, upland brush, and sodded openings were especially important to deer forage production.

Understory Cover

Deer use was significantly greater ($\chi^2 = 7.29\text{-}69.13$, 2 df, $P < 0.05$) where understory woody cover was present within all upland habitats except white pine (Table 5). Generally, deer use tended to be greater if deciduous saplings/tall shrubs were present in the understory of upland habitats, and to a lesser degree where pine saplings were present.

DNR PHOTO

Although deer use of oak habitats was low in this study, deer feed heavily on acorns when they are available.

Table 5. *Mean (± SE) number of deer trails per transect segment in the principal upland habitats as influenced by understory characteristics. Number of segments in sample in parentheses.*

	Dominant Understory			
Overstory Type	**None**	**Pine Saplings**	**Tall Shrub/Deciduous Saplings**	***P*[a]**
Open	0.14 ± 0.14 (7)	0 (3)	2.0 ± 0.34 (17)	0.0018
Aspen	1.09 ± 0.06 (267)	1.13 ± 0.14 (64)	1.44 ± 0.09 (161)	0.0038
Jack pine	0.87 ± 0.06 (323)	1.15 ± 0.10 (108)	1.52 ± 0.07 (237)	0.0001
White pine	0.73 ± 0.09 (85)	0.90 ± 0.12 (72)	1.01 ± 0.10 (128)	0.3282
Mixed hardwoods	0.64 ± 0.13 (44)	0.44 ± 0.17 (18)	1.00 ± 0.14 (39)	0.0261
Oak	0.46 ± 0.03 (437)	0.87 ± 0.07 (177)	1.00 ± 0.07 (219)	0.0001
Red pine	0.46 ± 0.05 (277)	0.86 ± 0.14 (42)	0.95 ± 0.14 (59)	0.0001

[a] Differences between means among the 3 categories determined by the Kruskal-Wallis test ($\alpha = 0.05$).

Table 6. *Significance levels of tests of deer use relative to the presence of understory in forested (aspen/oak/jack pine and red pine/white pine) habitats.*[a]

	Red Pine with		White Pine with	
Overstory/Understory Combination	**Deciduous Saplings/ Tall Shrubs**	**Pine Saplings**	**Deciduous Saplings/ Tall Shrubs**	**Pine Saplings**
Aspen				
w/deciduous saplings/tall shrubs	0.0017	0.0023	0.0004	0.0004
w/pine saplings	0.3083	0.2672	0.2468	0.2169
Oak				
w/deciduous saplings/tall shrubs	0.4855	0.4379	0.6846	0.3297
w/pine saplings	0.9981	0.9165	0.6051	0.8297
Jack Pine				
w/deciduous saplings/tall shrubs	0.0001	0.0001	0.0001	0.0001
w/pine saplings	0.1388	0.1210	0.1590	0.0798

[a] Differences between means among the various categories were determined by the Kruskal-Wallis test with Bonferonni adjusted $\alpha = 0.008$.

Deer use was greater (χ^2 = 9.29-24.56, 1 df, P = 0.002-0.0001) in aspen and jack pine with a deciduous understory present than in any red and white pine habitats (Table 6). In contrast, when aspen and jack pine habitats contained a pine sapling understory, deer use was no different ($P >$ 0.07) than in red and white pine. For all three of the understories, deer activity in oak was not different ($P >$ 0.05) than in red or white pine habitat. Aspen and jack pine habitats with deciduous understories were the most preferred of the upland forested habitats in this study. While red pine was the least-preferred overstory type, the presence of deciduous understory within red pine stands improved deer habitat quality.

Table 7. *Mean (± SE) number of deer trails per transect segment in the principal upland habitats as influenced by the presence of ground-layer forage. Number of segments in sample in parentheses.*

Overstory Type	Forage Present	Forage Absent	*P*[a]
Open	2.00 ± 0.33 (10)	0.88 ± 0.37 (17)	0.0139
Aspen	1.21 ± 0.06 (356)	1.20 ± 0.09 (136)	0.9530
Jack pine	1.29 ± 0.07 (262)	1.05 ± 0.05 (406)	0.0052
White pine	0.94 ± 0.09 (141)	0.86 ± 0.08 (144)	0.5559
Mixed hardwoods	0.73 ± 0.11 (59)	0.76 ± 0.14 (42)	0.9880
Oak	0.70 ± 0.04 (475)	0.68 ± 0.05 (358)	0.6869
Red pine	0.98 ± 0.09 (138)	0.35 ± 0.04 (240)	0.0001

[a] Differences between the means were determined by the Kruskal-Wallis test ($\alpha = 0.05$).

Table 8. *Significance[a] level of paired comparisons of overstory forest types with forage present.*

Overstory Type	Jack Pine	Aspen	Red Pine	White Pine	Mixed Hardwoods	Oak
Open	NS[b]	NS	NS	NS	<0.001	<0.001
Jack pine		NS	NS	0.001	<0.001	<0.001
Aspen			NS	NS	<0.001	<0.001
Red pine				NS	NS	NS
White pine					NS	NS
Mixed hardwood						NS

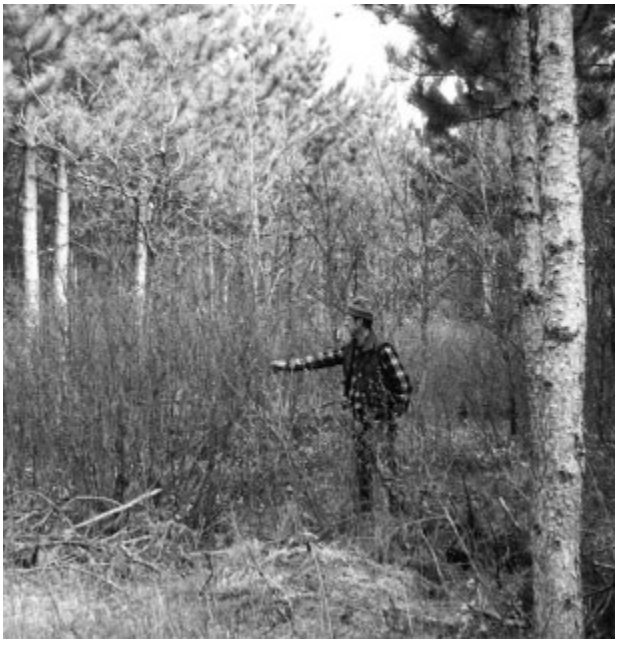
[a] Bonferroni adjusted critical value $\alpha = 0.002$.

[b] Not significant, $P > 0.001$.

Ground-Layer Forage

Deer use was significantly greater ($\chi^2 = 6.06$-50.90, 1 df, $P < 0.05$) in open, jack pine, and red pine habitats if ground-layer forage were present (Table 7). When ground-layer forage was present, deer use of open, aspen, jack pine, and oak habitats (principal candidates for conversion to red or white pine) was no different ($P > 0.05$) than in red and white pine habitats (Table 8). The only exception was higher deer use in jack pine than in white pine habitats with ground-layer forage present ($\chi^2 = 10.76$, 1 df, $P = 0.001$). Where ground-layer forage was absent, deer use was greater ($\chi^2 = 27.57$-88.70, 1 df, $P < 0.001$) in aspen, jack pine, and oak than in red pine (Table 9). Of 378 segments in red pine, 240 (63%) were without ground-layer forage.

These results illustrated the relative importance of ground-layer forage to deer in aspen, jack pine, oak, and red and white pine habitats. They also illustrate the relative importance of aspen, jack pine, and oak versus red pine, if ground-layer forage is absent.



DNR PHOTO

Deciduous understory cover increased the value of red pine plantations for deer and ruffed grouse.

DNR PHOTO

Deer use was lowest in red pine plantations, especially if understory or ground-layer forage were not present.

Ground-layer perennials and herbs have been considered to compete with conifers, and various methods have been attempted to control these species. However, research in Minnesota (Ohmann 1984) found that the presence of ground-layer flora did not reduce pine survival below acceptable levels. In addition, the effectiveness of control efforts were of limited duration. Ten years after treatment the species composition and biomass of ground-layer flora were similar between treated and naturally regenerated pine plantations. The presence of ground-layer flora increases within-stand diversity and the value of pine plantations for deer.

Drumming Ruffed Grouse Use of Red Pine Plantations

Densities of drumming males averaged 1.0 birds/100 acres in red pine plantations on converted sites during 1986-88, years during which regional grouse populations were near the midpoint between cyclic highs and lows (Table 10). Densities varied from 0.2 males/100 acres in 43- to 57-year-old stands to 1.7 males/100 acres in 15- to 29-year-old stands. Higher grouse densities within younger pine stands was due largely to better stocking of understory woody species, as discussed later. Most older red pine constituted an inferior habitat for ruffed grouse because suitable understory woody cover was sparse or absent.

During the same period, drumming grouse densities averaged 2.4 (2.4-2.5) males/100 acres in aspen and 0.7 (0.6-0.7) males/100 acres in oak habitats aged 0-60 years old on Sandhill Wildlife Demonstration Area and the adjoining Wood

Table 9. *Significance[a] level of paired comparisons of overstory forest types with forage absent.*

Overstory Type	Jack Pine	Open	White Pine	Mixed Hardwoods	Oak	Red pine
Aspen	NS[b]	NS	NS	NS	<0.001	<0.001
Jack pine		NS	NS	NS	<0.001	<0.001
Open			NS	NS	NS	NS
White pine				NS	NS	<0.001
Mixed hardwoods					NS	0.002
Oak						<0.001

[a] Bonferroni adjusted critical value $\alpha = 0.002$.

[b] Not significant, $P > 0.002$.

Table 10. *Drumming grouse densities (number of males/100 acres) in red pine plantations on converted sites in eastern Jackson County during 1986-1988. Number of grouse in each age class in parentheses.*

Age Class in 1987 (years)	No. Acres	1986	1987	1988	3-Year Mean
15-29	1,128	1.7(19)	1.2(14)	1.3(15)	1.4(16)
43-57	1,004	0.2(2)	0.1(1)	0.2(2)	0.2(2)
Combined	2,132	1.0(21)	0.7(15)	0.8(17)	0.8(18)

County Wildlife Area (J. Kubisiak, Wisconsin Department of Natural Resources, unpublished data). Mean drumming grouse densities during 1968-1982 were 4.1 males/100 acres in aspen and 0.8 males/100 acres in oak habitats on the Sandhill-Wood County areas (Kubisiak 1985). Differences in grouse densities between aspen and oak were due primarily to the relative absence of understory woody cover in oak habitats.

Estimates of drumming grouse densities within major CFR habitats that were incorporated into the ruffed grouse habitat guidelines (Kubisiak and McCaffery 1985) were 0.5 males/100 acres in pine; 0.9 in oak; and 3.5 in aspen. Drumming grouse densities in pine were derived, in part, from a census on the 412-acre Anniversary Red Pine Plantation (ARPP) (McCaffery and Ashbrenner 1991) and the Stone Lake Experimental Area in northeastern Wisconsin (Kubisiak et al. 1980, McCaffery et al. 1996). Drumming grouse densities averaged 0.4 males/100 acres during 1978, 1987, and 1989-90 in the 40- to 52-year-old ARPP. At Stone Lake, densities averaged 0.1 males/100 acres in a sawlog-sized red pine stand, and 0.2 males/100 acres in pole-sized jack pine stands during 1976-87.

In Minnesota, drumming grouse densities averaged 1.1 males/100 acres in pine habitats compared to 7.3 males/100 acres in aspen (Gullion and Alm 1983). Habitats were composed of red, jack, white, and Scotch pine plantations and natural stands of pole and sawlog size, and 15- to 20-year-old aspen. Both groups of habitats had dense pockets of deciduous understory. Somewhat higher drummer densities (4.5 males/100 acres) occurred where aspen saplings occurred throughout 14- to 18-year-old pine plantations (Gullion 1990).

Drumming grouse in central Wisconsin occupied those portions of red pine plantations where the highest density of woody cover occurred. The density of woody stems > 5 ft tall within 12 ft of drumming sites averaged 652/acre for live saplings; 1,041/acre for live shrubs; and 107/acre for dead stems; for a total of 1,800 $\pm$ 445 (SE) stems/acre. Stocking of understory woody vegetation was lower ($t = 5.73$, 365 df, $P < 0.05$) at random sites in red pine plantations, averaging 604 $\pm$ 44 stems > 5 ft tall/acre. Included in this total were 342 saplings, 206 shrubs, and 56 dead stems. Although the overall density of understory woody stems > 5 ft tall was greater near drumming sites than in the remainder of the stand, habitat suitability for ruffed grouse was very low in the red pine plantations surveyed in our study. Most (17 of 27) drumming logs had stem densities lower than the minimum 2,000 stems/acre recommended by Cade and Sousa (1985). Additionally, only 5 of 27 drumming sites had the minimum of 20 mature aspen within 100 yards of the drumming log that was prescribed as a key factor in the habitat suitability index (Cade and Sousa 1985).

Drumming grouse tended to choose the best available cover within pine plantations, as was reported in northeastern Wisconsin (McCaffery and Ashbrenner 1991, McCaffery et al. 1996) and Minnesota (Gullion 1990). In the ARPP, drumming grouse occupied sites where residual hardwood saplings (white birch or sugar maple) or balsam fir provided suitable understory cover. At Stone Lake, drumming grouse occupied mature sawlog red pine with a white pine and hardwood-beaked hazel understory, and jack pine with a sparse tall shrub understory. In Minnesota, drumming grouse occupied 14- to 18-year-old pine plantations, where a high density (7,800-23,000 stems/acre) of beaked hazel, aspen, white birch, and speckled alder occurred.

Most drumming grouse occupied portions of red pine plantations where red pine trees provided the principal canopy cover and oak, red maple, and black cherry saplings the principal understory cover. Occupancy of red pine plantations appeared to be due, in part, to the lack of suitable understory woody cover in adjacent older pole-stage oak and aspen stands. Drummers may have preferred the dense overhead cover provided by red pine to the more open-grown hardwood stands nearby.

Vegetative Characteristics of Red Pine Plantations on Converted Sites

Basal area in red pine stands increased ($t = 6.90$, 338 df, $P < 0.05$) with age (Table 11), as did the proportion of the overhead canopy occupied by red pine ($t = 1.96$, 338 df, $P < 0.05$). In contrast, the number of red pine trees and saplings and understory shrubs > 5 ft tall was lower ($t = 2.4$-5.8, 338 df, $P < 0.05$) in the older red pine stands that were thinned once. Vegetation characteristics of the two age classes may have also been influenced by site quality, overstory stocking levels, and the number of competing woody species that were allowed to survive after site preparation and planting, but these parameters were not assessed.

The most prevalent shrubs (IV $\geq$ 1.0) in pine plantations included blueberry, dewberry, huckleberry, and hazel-nut (Table 12). Prevalent under-

Table 11. *Mean (±SE) vegetative characteristics of red pine plantations on sites converted from aspen and oak in eastern Jackson County, 1987.*[a]

Age Class Years	Site Index	Basal Area (ft^2)		% Canopy Cover			Stems/Acre					
							Red Pine		All Species			Dead
		Red Pine	All Trees	Red Pine	Hard-woods	Open	Trees	Saplings	Trees	Saplings	Shrubs	Stems
20-26	50-70	104±2	111±2	64±2	6±1	30±1	423±13	54±4	466±15	214±18	326±72	27±4
48-57	50-80	128±3	136±3	69±2	11±1	20±1	316±13	42±3	394±16	470±34	86±17	86±7

[a] Vegetative measurements were made in six 20- to 26-year-old and seven 48- to 57-year-old stands during summer 1987.

story trees included red maple and oak. Principal summer herbs included grass-sedge (principally *Carex pensylvanica*), bracken fern, and mosses. Less common herbaceous species constituted the remainder of ground-layer flora. Various lesser perennial herbs and woody plants (IV < 1.0) that also occurred in the red pine plantations surveyed are listed in Appendix A.4.

Most of the understory trees and shrubs commonly found in central Wisconsin red pine plantations are important food for deer and ruffed grouse (Habeck 1959, Vanderschaegen and Moulton 1975, Rogers et al. 1981, Servello and Kirkpatrick 1987, Barber et al. 1989). In addition, many of the summer herbs that frequently occur in plantations are preferred by deer and ruffed grouse. The occurrence of understory and ground-layer forage plants in the surveyed red pine stands increased the value of these stands for deer and ruffed grouse. Ground-layer shrubs and perennial herbs should be encouraged wherever they occur.

Summary and Management Considerations

Aspen, open, and jack pine were valuable habitats for deer in this study. Conversion of these habitats to red or white pine without retaining understory and ground-layer food and cover plants important to deer could reduce deer carrying capacity. Lower deer use occurred in oak, white pine, and red pine than in aspen, open, and jack pine. Deer use was greatest with a deciduous understory, intermediate where pine saplings were present, and lowest where understory shrubs and saplings were absent. Higher deer use also occurred in aspen and jack pine with deciduous understories than in red or white pine, whatever woody understory was present. By comparison, deer use of oak was not different than red pine or white pine, with deciduous saplings/tall shrubs or pine saplings present.

Table 12. *Importance Values of the principal ground-layer plants browsed by deer in red pine plantations in eastern Jackson County, 1987. Only species with IV ≥ 1.0 are listed.*

Common Name	20- to 26-Year-Old Stands	48- to 57-Year-Old Stands
Ground-layer shrubs		
Blueberry	10.3	8.6
Dewberry	3.6	2.9
Wintergreen	0.9	3.7
Huckleberry	2.7	5.3
Trees and tall shrubs		
Red maple	1.4	4.6
Oak	3.2	2.3
Hazel-nut	2.7	1.9
Blackberry	3.0	0.6
Other plants		
Grass-sedge (principally *Carex pensylvanica*)	13.4	6.0
Bracken fern	6.4	4.2
Mosses	6.2	6.3
Other summer herbs (Included aster, bellwort, cinquefoil, hawkweed, prairie loosestrife, violet, wild lily of the valley, and wood anemone)[a]	5.8	4.3
Inanimate		
Litter	32.8	32.3
Dead wood	7.6	9.9

[a] Results for other herbs represented combined IV whenever one or more species was present.

PHOTO: J. KUBISIAK

White pine habitats provided more understory cover and ground-layer forage for deer than did red pine habitats.

Results demonstrated the importance of preserving or encouraging understory and ground-layer woody cover and forage plants to maintain more optimal habitat for deer and ruffed grouse, particularly on sites scheduled for conversion to red pine or white pine. Understory woody cover enhanced habitat quality for deer within all upland habitats except white pine. Understory woody cover also improved habitat quality for ruffed grouse within red pine plantations, although ruffed grouse occurred at very low densities at these sites, compared to aspen habitats. With ground-layer forage present in red pine, deer use was similar to that in aspen, jack pine, and oak. Conversely, with ground-layer forage absent in red pine, deer use was much lower.

Conversion of open, aspen, oak, and jack pine to red pine has continued to occur on public lands in the CFR. This has resulted, in part, from the application of broad compositional guidelines defined in MC 2112 and the DNR Silviculture and Forest Aesthetics handbook (Wisconsin Department of Natural Resources 1990). In recent years, application of the ecological classification system developed by Kotar et al. (1988) and Kotar and Burger (1991) for forest habitats in northern Wisconsin has received greater attention in the CFR. This approach provides criteria to better define the capability of a habitat type, including the species best suited for the site, strength of successional trends, and expected productivity. This remains a useful guideline to encourage a broad range of habitats.

Current overwinter deer population goals average 28 deer/mi^2 in the CFR. If the management objective is to maintain the existing deer habitat suitability in the region, management should strive to optimize regional habitat diversity and within-stand species diversity, avoiding large-scale conversion to monotypic red and white pine habitats.

Although deer use of oak habitats was relatively low in this study, we urge caution in the conversion of existing oak habitats to red and white pine, given the demonstrated importance of acorns for deer and the natural loss of oaks from oak wilt and succession. We recommend maintaining oak where it occurs in smaller stands (<20 acres) or where oak comprises a small proportion (<20%) of CFL in a management unit.

The detrimental effects of conversion to red and white pine plantations can be partially mitigated by managing them near the minimum recommended stocking (e.g., about 200 overstory trees [9 in dbh] per acre at 80 ft^2 basal area as defined by Benzie 1977) to favor a greater variety of understory woody cover and ground-layer forage plants. Herbicides should either be avoided or selectively applied to maximize survival and growth of understory woody and ground-layer forage plants.

Although not assessed in this study, we believe that maintaining a high interspersion of forest types and age classes may lessen the negative effect of pine conversion. Natural openings that allow native understory woody and herbaceous species to thrive should be encouraged within plantations to benefit deer. Within larger pine plantations (>20 acres), at least 5% of the area should be kept in well-distributed small (0.75-1 acre) deciduous or herbaceous openings, as recommended by McCaffery and Ashbrenner (1991) on areas dominated by heavier soils. Schone et al. (1984) and Bassett (1984) also suggest leaving small areas in natural vegetation within red pine plantations > 50 acres. In New York, ruffed grouse and songbirds were also oriented toward openings and edges of plantations where native forage plants

were more abundant (Smith 1958, Bailey and Alexander 1960).

An alternate approach to maintaining regional deer and ruffed grouse habitat suitability may be possible. If managers desire to maximize timber production on some sites through high stocking rates and suppression of competing species, the reduction in local habitat suitability could be offset by enhancing habitat suitability on other neighboring sites. However, little is known of the effect of differing size, shape, and arrangement of habitat patches within a landscape on deer and ruffed grouse habitat suitability. This approach will require close coordination between forestry and wildlife management personnel in the region.

Conversion of openings, jack pine, and deciduous forest types to red pine is especially being pursued on industrial forest lands. In addition, cutting prescriptions that favor white and red pine or red maple over aspen and jack pine are expected to reduce habitat suitability for deer and ruffed grouse on private non-industrial forest lands. Lastly, potential conversion of private non-industrial forest lands to cropland, residential, and commercial uses would further reduce habitat suitability. Therefore, public forest lands in the region will likely have an increased role in the maintenance of regional habitat suitability for these species.

PHOTO: J. KUBISIAK

Habitat suitability of pine plantations for deer and ruffed grouse can be enhanced by retaining understory and ground-layer food and cover plants.

PHOTO: J. KUBISIAK

Small openings within pine plantations provide food and cover for deer and ruffed grouse.

Research Needs

Increased conversion to conifers has several other implications that need to be addressed. Better information is needed to determine the long-term implications (cost-benefit) of pine conversion, expected increase in timber production, and potential effect on deer, ruffed grouse, and other wildlife. The optimum size and arrangement of pine plantations needs to be better defined to minimize damage or loss by insects, disease, wildfire, or extreme weather events including ice or wind storms, while maintaining commercially operable stands within acceptable guidelines to maximize habitat diversity.

The feasibility of prescribed burning or scarification to improve the stocking of aspen, oak, or jack pine, and some natural stands of red and white pine should be examined as alternatives to encouraging conversion to red or white pine plantations. In addition, more work is needed to determine the effects of chemical treatments associated with intensive pine culture on soil and above-ground invertebrates, the soil mineral balance, and vigor of native understory woody and herbaceous plants important to deer, ruffed grouse, and other wildlife.

Additional information on the influence of size, shape, and arrangement of habitat patches within a landscape on regional habitat suitability would benefit the development of regional ecosystem management strategies. Lastly, a greater understanding of the ecological effects of differing deer population goals is needed.

Appendixes

Appendix A.1. *Habitat composition (acres) of the five forest survey units on the Black River State Forest (BRSF) and Jackson County Forest (JCF), 1985.*

			Habitat Type								
Unit	Acres	Mi^2	Aspen-White Birch	Oak	Jack Pine	Red Pine	White Pine	Swamp Conifers	Mixed Hard-woods	Grass-Upland Brush	Lowland Brush-Marsh
BRSFN	9,577	15.0	452	1,267	4,713	1,520	948	—	208	34	435
JCFW	12,555	19.6	895	4,226	4,305	1,299	931	61	58	211	569
BRSFS	10,810	16.9	590	4,017	1,379	2,194	440	375	554	—	1,261
JCFN	12,964	20.3	3,252	3,698	1,587	1,117	340	310	65	195	2,400
JCFS	12,655	19.8	4,307	1,565	29	1,754	104	358	21	57	4,460
Sum	58,561	91.6	9,496	14,773	12,013	7,885	2,763	1,104	906	497	9,125
%			16.2	25.2	20.5	13.5	4.7	1.9	1.5	0.8	15.6

Appendix A.2. *Characteristics of surveyed red pine plantations in eastern Jackson County.*

Forest Survey Unit	Name	Origin (Year)	Acres	Soil Type[a]	Site Index	Habitat Type[b]	Type of Survey	
							Vegetation	Ruffed Grouse
BRSFN	Highbank	1939	75	2	70	PCr	X	X
	Old 54	1938	117	1	46/50	PRhl	X	X
	Jungle Road	1930/1939	297	1	50/59	PRhl	X	X
	Clay School	1938	8	0	55	PGy	—	X
	Cemetary Road	1939	88	0	60	PGy	X	X
	Hryz Road	1938	55	0	50	PRhl	X	X
BRSFS	Stanton Creek North	1961/1965	97	0	70/50	PGy	X	X
	Stanton Creek South	1964	104	0	80	PGy	X	X
	North Settlement North	1965	68	0	70	PRhl	X	X
	North Settlement South	1938	94	0	70	PRhl	X	X
	Shale Road West	1972	57	1	55	PGy	—	X
	Shale Road East	1967	69	0	55	PGy	—	X
JCFN	McKenna Road [c]	1944/1964	297	0	50/60	PGy	X	X
	Lone Pine North	1938	168	0	50/55	PGy	X	X
JCFS	Lone Pine South	1962/1965	260	0	50/60	PGy	X	X
	Goodyear	1958	23	0	50	PGy	—	X
	Bear Bluff	1964/67	255	0	50/60	PGy	X	X

[a] 0 - Sand, 1 - Loamy Sand, and 2 - Sandy Loam.

[b] Habitat types according to Kotar and Burger (1991).

[c] 102 acres planted in 1944 and 195 acres planted in 1964. Only the 1964 planting contained ruffed grouse and was measured for vegetation characteristics.

Appendix A.3. *Changes in the acreage of commercial forest land in the Central Forest Region.*[a]

Forest Type	Acres (x 1,000) (% of commercial forest land) 1968	1983	% Change in Acreage
Jack pine	170.4 (10)	194.3 (11)	+14
Red pine	71.2 (4)	81.2 (5)	+14
White pine	41.9 (2)	47.8 (3)	+14
Swamp conifer	38.2 (2)	24.7 (1)	-35
Oak-hickory	561.7 (33)	681.5 (38)	+21
Mixed hardwoods[b]	299.0 (18)	275.4 (15)	-8
Aspen-white birch	463.8 (27)	463.2 (26)	—
Non-stocked	58.5 (3)	11.8 (<1)	-80
Total	1,704.7 (100)	1,779.9 (100)	+4

[a] Includes Adams, Clark, Eau Claire, Jackson, Juneau, Monroe, and Wood County.

[b] Includes elm, ash, maple, and yellow birch.

Appendix A.4. *Relative abundance (Importance Value) of the less common ground-layer plants (IV < 1.0) in red pine plantations of eastern Jackson County, 1987.*

Common Name	20- to 26-Year-Old Stands	48- to 57-Year-Old Stands
Perennial herbs		
Strawberry	0.06	0.15
Bunchberry	——	0.59
Shinleaf	0.06	——
Clubmoss	——	0.15
Trees and shrubs		
Black cherry	0.19	0.26
Trembling aspen	——	0.18
White birch	——	0.16
Sweetfern	0.84	0.15
Rose	0.54	0.53
Bush honeysuckle	0.19	0.71
Service-berry	0.07	0.46
Red osier dogwood	——	0.43
Chokeberry	0.13	0.04
New Jersey tea	0.13	——
Meadow-sweet	0.07	——
Red raspberry	0.08	——
Leather-leaf	——	0.06
Willow	——	0.04
Trailing arbutus	——	0.04

Appendix B.1. Common and scientific names of plants cited in text.[a]

Common Name	Scientific Name	Common Name	Scientific Name
Alder, speckled	*Alnus rugosa*	Hazel-nut	*C. americana*
Anemone, wood	*Anemone quinquefolia*	Hickory	*Carya spp.*
Ash	*Fraxinus spp.*	Honeysuckle, bush	*Diervilla lonicera*
Ash, white	*F. americana*	Huckleberry	*Gaylussacia baccata*
Aspen, large-toothed	*Populus grandidentata*	Leather-leaf	*Chamaedaphne calyculata*
Aspen, trembling	*P. tremuloides*	Loosestrife, prairie	*Lysimachia quadrifolia*
Aster	*Aster spp.*	Maple, red	*Acer rubrum*
Bellwort	*Uvularia sessilifolia*	Maple, silver	*A. saccharinum*
Birch, bog	*Betula pumila*	Maple, sugar	*A. saccharum*
Birch, white	*B. papyrifera*	Meadow-sweet	*Spiraea latifolia*
Birch, yellow	*B. lutea*	Mosses	*Sphagnum spp. and others*
Blackberry	*Rubus allegheniensis*	New Jersey tea	*Ceanothus americanus*
Blueberry	*Vaccinium spp.*	Oak, black	*Quercus velutina*
Blueberry, low sweet	*V. angustifolium*	Oak, jack-	*Q. ellipsoidalis*
Bunchberry	*Cornus canadensis*	Oak, white	*Q. alba*
Cherry, black	*Prunus serotina*	Pine, jack	*Pinus Banksiana*
Cherry, choke	*P. virginiana*	Pine, red	*P. resinosa*
Chokeberry	*Aronia melanocarpa*	Pine, Scotch	*P. sylvestris*
Cinquefoil	*Potentilla spp.*	Pine, white	*P. strobus*
Clubmoss	*Lycopodium spp.*	Raspberry, red	*Rubus strigosus*
Dewberry	*Rubus spp.*	Rose	*Rosa spp.*
Dewberry, swamp	*R. hispidus*	Sedge	*Carex spp.*
Dogwood, gray	*Cornus racemosa*	Sedge	*C. Pensylvanica*
Dogwood, red osier	*C. stolonifera*	Service-berry	*Amelanchier spp.*
Elm	*Ulmus spp.*	Shinleaf	*Pyrola spp.*
Elm, American	*U. americana*	Spruce, black	*Picea mariana*
False Solomon's seal	*Smilacina racemosa*	Strawberry	*Fragaria virginiana*
Fern, bracken	*Pteridium aquilinum*	Sweetfern	*Myrica asplenifolia*
Fern, cinnamon	*Osmunda cinnamomea*	Tamarack	*Larix laricina*
Fir, balsam	*Abies balsamea*	Trailing arbutus	*Epigaea repens*
Goldthread	*Coptis groenlandica*	Violet	*Viola spp.*
Grass, bluejoint	*Calamagrostis canadensis*	Wild lily of the valley	*Maianthemum canadense*
Grasses	*Panicum spp., Poa spp., others unknown*	Willow	*Salix spp.*
		Winterberry	*Ilex verticillata*
Hawkweed	*Hieracium spp.*	Wintergreen	*Gaultheria procumbens*
Hazel, beaked	*Corylus cornuta*		

[a] Gleason and Cronquist (1963).

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